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Optimizing Quality of a System Based on Intelligent Agents for E-Learning

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Abstract

Distributed Artificial Intelligence is a subfield of artificial intelligence systems, that aims to build intelligent agents, that can make decisions in order to achieve their goals and are set in a world populated by other intelligent agents (artificial or human) who in turn have their own purposes. In this paper we have presented intelligent agents for e-learning. From quality perspective, the system presented indicates a way to search for concepts in a distributed e-learning environment. Based on the requirements of ISO 27000, we reviewed the stages for creating the system. Initially, higher ranking agents interrogate the server's local knowledge base agents without modelling them. Then, the agents shape the knowledge bases from the servers to avoid asking the same question twice if the local agent does not know the answer. Further, it introduced the possibility for agents to cooperate, so that they can ask questions of each other if they are on the same server. Finally, priority queues were implemented on the servers, so that only a fixed maximum number of agents could be served at a time, in a descending order of priorities.

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1. Introduction

The paper is structured into several sections, each detailing an important aspect of the proposed system. This section presents the main reasons for developing distributed artificial intelligence applications and attempts to define a software agent. The next section "E-learning - the conceptual frame" contains definitions and descriptions of the e-learning system as well as the virtual educational institution. The major causes for the development of e-learning are

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discussed and the important advantages mentioned. The section “Intelligent agents for e-learning” lists the technologies that have the greatest chance of successfully implementing e-learning and it gives a brief overview of each. The forth section “The selection of e-learning solutions” includes a method for selecting the most appropriate e-learning system for an institution and provides some advice on customising the discussed method. The section “Structure of an e-learning system” gives the details to the proposed software agent system used for e-learning purposes based on the requirements of ISO 27000 standard. The system uses the well-known BDI architecture and is based on the exchange of knowledge items though various complex negotiations. In the section “Behaviour”, the inner workings of the software agents used in the system are debated. The later section “Possibilities of cooperation between agents” notes possible improvements to the previous system to comply with the ISO 27000 requirements and analyses their impact. Section „Introduction of priority queues on servers” further develops the earlier proposed improvements with additional changes and reviews their impact as well. The “Conclusions” section summarises the main points of this paper.

The notion of agent can have different interpretations depending on the particular field that it is used in. In terms of software, an agent is a program that behaves similarly to a human agent, such as an agent of a travel agency or an insurance agent. In essence, this term refers to a program that has a social interface metaphor, meaning it is able to communicate intelligently with other software agents or persons.

A relevant description of the notion of agent can be given by listing the basic characteristics that an agent must possess (Wooldridge, Jennings, 1995): (1) autonomy: an agent operates without human intervention, takes initiative and exercises control over his own actions. The agent accepts requests from users but ultimately decides how and where to meet those demands. At the same time the agent does not blindly respond to orders received but works with users or other agents to meet their demands, and may propose amendments or ask for further clarification; (2) reactivity: agents perceive the environment around them (which may be the physical world, a user via an interface, a collection of other agents or the Internet) and respond timely to the changes noticed in this environment; (3) communication and social skills: an agent must be able to engage in complex communication and dialogue with other agents or people to get information or help in meeting goals.

The model or architecture of agents can range from very simple automatic structures, such as reactive agents, up to complex knowledge structures with sophisticated representation, reasoning and decision-making capabilities, structures encountered in cognitive agents, called rational agents.

2. e-Learning – The Conceptual Frame

The Internet is gradually becoming the access arbitrator to education and culture. The most appropriate form to meet the knowledge and training needs is e-learning.

An e-learning system (a system of distance learning or virtual education) is a planned teaching-learning experience, organized by an institution that provides material immediately in a sequential and logical order to be assimilated by students in their own terms, without compelling them to work in a synchronized way. Mediation is done through various ways, from material on diskette or CD (and possibly by mail) to content transmission over the Internet. The interactive learning system is a collaborative educational system that allows multiple participants located in different geographical locations to interact in a virtual three-dimensional space. To perform virtual experiments creative tasks can also be used. E-learning is generally defined as electronic-based learning. Whether user access is achieved through a browser (the Internet or an intranet) or by other means, such as CD-ROMs, the main tendency is to increase flexibility and availability by harnessing the advantages provided by the continuously expanding global network of the World Wide Web.

Virtual institutions

A virtual education institution can be defined as:

• An institution involved in educational activities that promotes its curriculum and courses directly to those interested through the use of information and communication technologies as well as providing tutorial support.

• An organization created by a partnership to facilitate teaching and learning without direct involvement, by supplying educational programs.

Examples of virtual institutions include both the public and the private sector at the elementary, secondary and university level as well as forms of non-formal education, continuous education, vocational and professional training.

The emergence of virtual institutions is due to four different factors:

• Institutions have been involved in open and distance education.

• Traditional institutions, from schools to universities, which have not been involved in distance education before. These institutions are beginning to apply the new information technologies as support for increased quality, increased productivity and flexibility, with the premise that this will reduce costs and attract revenue by attracting new students. This transition occurs in the typical situation of specific projects that create a virtual institution within a traditional one.

• Corporations or large organizations that develop training programs for internal use having as a support and means of distribution the information and communication technologies and labelling it as virtual.

• Individuals who, for reasons ranging from altruism to profit use these technologies to create learning opportunities for anyone interested.

The label “virtual” is used broadly and indiscriminately all over the world and is interchangeable with other terms such as open and distance learning, distributed learning, network learning, Web-based learning and computer-based learning. Currently, there are very few examples of institutions that use information and communication technologies to cover all functions included in the definition of virtual education. The most common applications of new technologies are found in the management, preparation and distribution of the supporting materials and where the possibility exists, in the tutoring activities, in the form of student-student and student-teacher interactions.

The emergence of virtual institutions is directly related to infrastructure development and access to information and communication technologies. Cost reduction is often cited as a goal to justify introducing new information technologies in education and training institutions. But valid data on the costs issue is insufficient.

The continuous growth of the capacity and flexibility of the new information technologies with applicability in educational situations, coupled with a continuous decrease in the cost of equipment as well as the technological capacity to facilitate the operation of certain traditional structures of institutions - are arguments that convince policy makers to embrace change and to accept a dual organization - which is otherwise a model of distance education frequently encountered.

E-learning was constantly improved and thusly can now include animations based on context, simulations and interactive tasks in addition to traditional audio-visual methodology. The content can be transmitted within electronic discussion forums, through distance learning, documents and online tests and may increase the efficiency of lessons because of cost efficiency. The main advantages are (Carson MediaInc, 2003):

• Prompt training: Users can be trained as the program allows and based on the learning rate of each participant. This greater availability helps employees to better manage their time;

• Operation based on the browser: Content is presented in the familiar environment of a web browser. Many employees are connected to a corporate network or have Internet access;

• Ease in updating: Changes are made on the server that stores content and updating can be accessed immediately;

• Global availability: e-learning courses can be accessed from virtually anywhere, which involves cancellation of distribution costs for geographically distributed users.

3. Intelligent Agents for e-learning

Many researchers have studied the ways in which e-learning can be made practical. Two technologies have the greatest chance to contribute to the successful implementation of e-learning (Hill, 2003):

• The Vortals (vertical or niche portals): these are specialized and dedicated portals that adapt specific collaborative learning strategies to increase performance and provide necessary information. A learning portal must provide different interfaces for different types of users: a specific interface for a student who prefers visual-based learning, another for a student who prefers a hearing-based learning and other interface for kinaesthetic student. As the user gains experience, the most common selected options must replace the original default. The more personalized the portal is, the greater is its impact;

• Intelligent agents: these are tools that can manage the information overload, can serve as theoretical experts and can create programming environments for users (Baylor, 1999). In this way, learning is enhanced by the existence of several agents (multiple agent systems) that are collaborating or competing to achieve predetermined goals.

Intelligent agents must be able to model the profile of the user to be able to store his/hers knowledge, skills and learning style. Intelligent agents for e-learning are autonomous software tools coupled with other software applications and databases running in a computer environment. The main function of an e-learning intelligent agent is to help the user to interact with an application that offers a field of learning (Gâlea, Leon, Zaharia, 2003). As it was mentioned before in this article, they base their educational potential on three main educational dimensions (Baylor, 1999): can manage information overload, can serve as pedagogical experts and can even create user programming environments for students.

While the concept of distance education provides a more convenient virtual access for students from any geographical location, it also introduces some limitations and shortcomings (Jafari, 2009), especially in the communication, collaboration, education and course administration areas. One of the most important limitations is the lack of a "face-to-face" interaction between teacher and student. By using intelligent agents in a learning environment, some of these limitations can be overcome.

Thus, an intelligent agent must always be available for students, to understand and interpret student problems (questions and requests), to have or know a set of actions to be activated in accordance with the recognition of student needs and responses and decisions must depend on the course program, the student's progress, its individual problems and special interests (Gadomski, Fontana, 2001).

4. The selection of e-Learning solutions

More than just a new type of education and distance learning, an eLearning system is a business solution and a successful option for institutions offering training. In a feasibility study to implement a system of e-learning, the comparison between the different solutions on the market can be made through a series of defining indicators for a distance learning system:

- **scale** - the number of participants involved in a learning activity for a specified period; also includes the distance between the participants, covered by the system;
- **perception** - the technical quality of materials received by participants (from realistic graphics and up to resolution);
- **symmetry** - the degree to which attention can focus on each participant (inversely proportional to class size);
- **interactivity** - minimum length of time in which a response to an interaction can be obtained; means - the range of means / work tools available to participants for learning and communication;
- **control of the student** - the degree to which the student can be active, can collaborate with other students or teachers for meeting the learning objectives;
- **integration capacity** - the ability to present information in different ways and from various sources;
- **costs** - costs that a student incurs in order to achieve a stable set of objectives;
- **time** - the level of control over time that the student has in order to achieve a learning objective (the possibility to assimilate the content in one's own rate);
- **flexibility** - the ease in which improvements can be made throughout the program.

The e-learning system was associated, in theory, with the terms of its desirable effects, transposed at the level of objectives as well, that incorporate values difficult to deny such as student-centricity and autonomy. By removing spatial and temporal obstacles or the imposition of a certain learning rate, study opportunities for large social groups is ensured, without interrupting their professional activities. This is actually the main feature that makes the system viable for courses of higher education, for continuous education, for vocational education and potentially places it among the most requested types of education systems of the future.

5. Structure of an e-learning system

The proposed system consists of a number of agent servers that are able to accommodate and transport agents in the network. Also, the servers hold knowledge bases that agents can browse through a local static knowledge base agent. Agents have BDI architecture (Belief-Desire-Intention). First the type of information that agents can manage will be described. The possibility for agents to seek distributed knowledge for an e-learning system has been studied. Thus, it was assumed that the knowledge items can be of two types (Gâlea, Leon, Zaharia, 2003): perceptive: knowledge that students who are studying can understand directly, without prior information (e.g. Concept of natural number or colour); extensive: knowledge that requires previous understanding of other concepts (e.g. a programming language cannot be understood without knowing what a computer is).

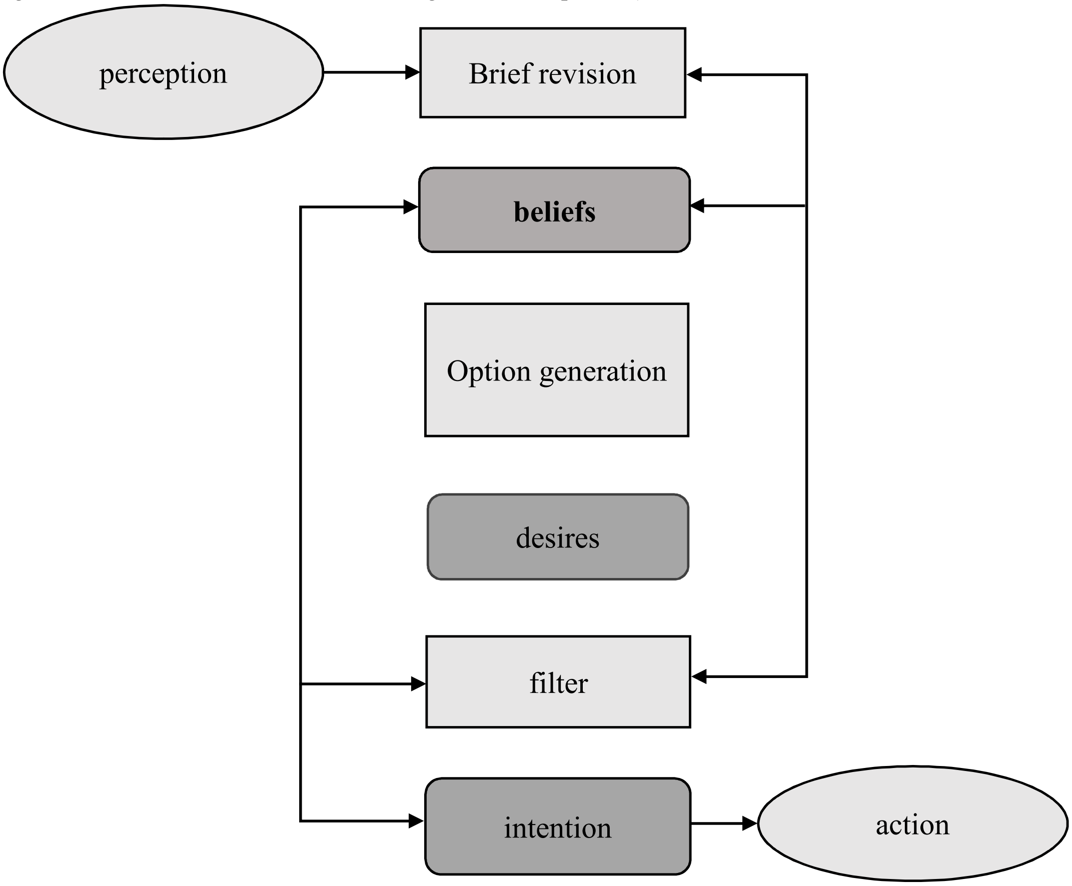

Figure 1: BDI architecture
Source: (Leon, 2006)

It was assumed that the knowledge items (KI) are based on a limited number of perceptive items. The system will be designed in a very general and flexible way, so that the student does not memorize specific information, only references to it. For example, if a certain concept requires a film and a text in order to be learned, the agent will find the reference to the film on a server and then continue seeking the necessary concepts for understanding the film and text. The agent will actually find a sub graph in the graph of knowledge, so that all relevant knowledge entities will directly or indirectly be based on perception. It is not practical for a mobile agent to carry a film across the network, but it is important to keep information on its location, because it can be downloaded at the right time.

The next figure shows an example of 4 perceptive knowledge items and 16 items of extended knowledge. For simplicity, we imposed that an extended knowledge item must rely on between two and four other items of knowledge (perception or extended).

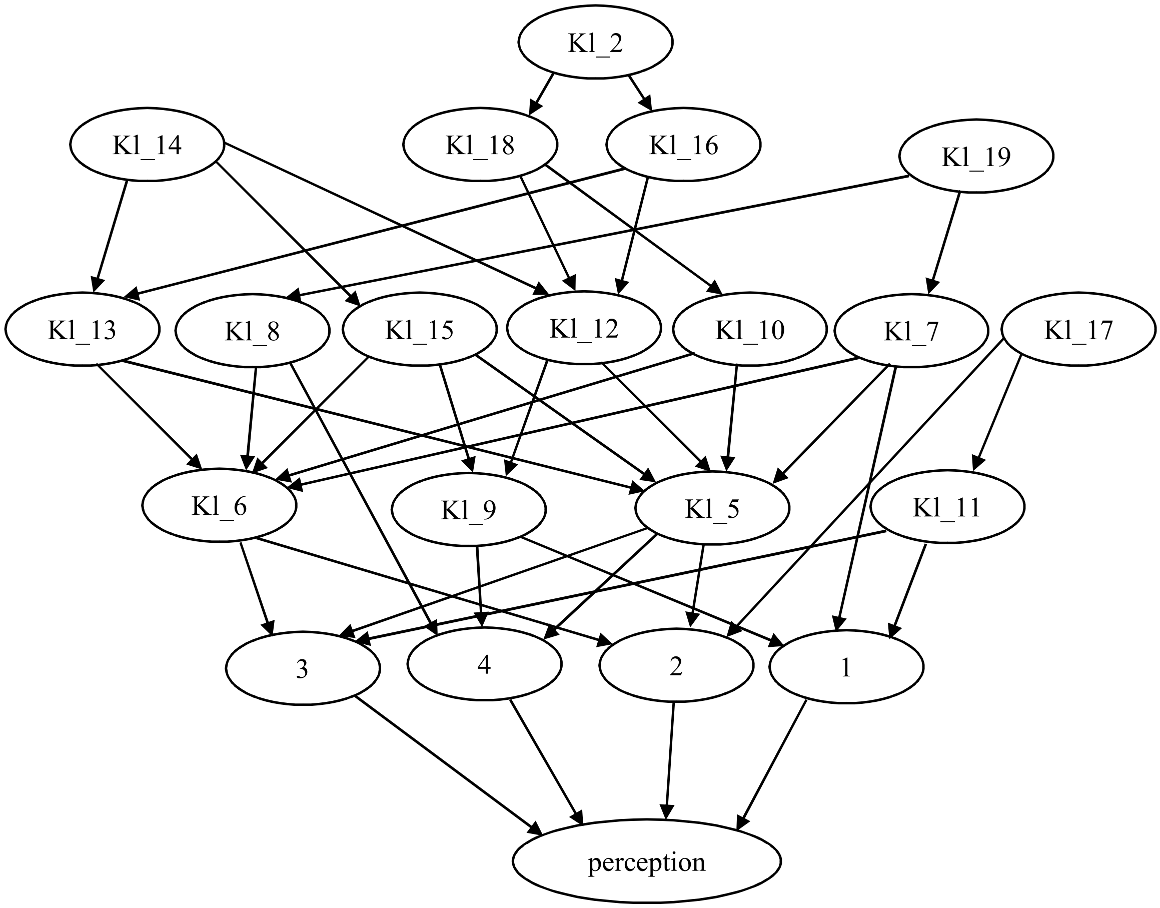

Figure 2. Knowledge Graf
Source: (Gâlea, Leon, Zaharia, 2003)

The knowledge base will include entities such as: KI_1 perceptive, KI_2 perceptive, KI_5 extends KI_3 KI_2, KI_14 extends KI_13 KI_8 KI_12. This knowledge base is distributed on the agent servers. An information redundancy of 20% has been accepted, i.e. the same information can be found with a probability of 20% in several local knowledge bases.

The desires of agents are initialized randomly. For example, a list such as: KI_5 KI_7 KI_14 KI_19 will require the agent to find a way from each of the four items of knowledge towards perception, by visiting the available servers. When an agent reaches a server, it asks the local knowledge base agent about the definitions of unknown concepts. Agents communicate through KQML messages (Knowledge Query and Manipulation Language). After the local static agent responds, the search agent adds the definitions to its list of beliefs and updates it`s desires. Concepts that are now defined are removed from the list of desires. However, if the concept extends other concepts that are not yet in the list of beliefs (concepts that the agent has not yet encountered) these must also be added to the list of desires.

Consider the following example: the agent has the reference KI_9 as a desire. If it receives the answer KI_9 extends KI_1 KI_4 it will remove KI_9 from the list of desires, will enter the answer in the list of beliefs and will generate two new desires: KI_1 KI_4. If it receives at some point the response KI_1 perceptive, the agent will not generate any new desire, because its purpose is to bring all references entities to a perceptive knowledge base. When the local agent has no answers, the search agent will randomly choose a still unfrequented neighbouring server to travel to it. After the agent has visited all servers, it is still possible to have more unfulfilled desires. In this case a new cycle of visits begins. The process continues until all entities from the list of desires are given direct or indirect perceptive definitions. If the agent has to find the sub graph of a concept on a high level in the conceptual hierarchy, it must find a subset with a large number of elements of a set of concepts. To fulfil its purpose several visitation cycles may be necessary.

Summarizing the above, the presented e-learning system consists of three entities:

• Servers: are responsible for providing a runtime environment for agents and for transporting the agents to neighbouring servers;

• Static Knowledge base agents: are agents that are distributed one for each server and are responsible for managing the local knowledge base; their primary role is to provide to the search agents the information requested;

• Mobile Search agents: are agents that store information in their own knowledge bases and can move from one server to another to perform tasks.

Servers have, besides the standard role of launching and transporting agents, two more distinct functions. Because search agents have priorities, the servers have the responsibility to control the priority queue of the search agents so that only a maximum number of agents can be run at a time. In this way overloading is avoided, since the queue size can be set dynamically, taking into account the performance of the computer where the server is installed. Also, the servers must check the security certificates so that only registered agents have access to the knowledge bases.

6. Behaviour

As was mentioned before, search agents have BDI architecture. Further in this article, the way agents respond to the occurrence of external events and how they represent their state internally will be analysed. The same behaviour can be described both in a state based manner and in an event-driven manner. Consider the behaviour of a search agent. He has lots of desires (which can be initialized by the user) and reaches a server. The agent requests from the local knowledge base agent the information needed to fulfil its desires. As it receives answers, it updates its beliefs and can generate new desires. When it no longer receives responses from a server, the agent randomly chooses a still unfrequented server and sends a request for transportation to that server. The choice is made in a random way in order to remove the subjective tendencies of a certain direction. When the agent fulfils all its desires, it returns to the server of origin reports to the user. This can be achieved in two ways:

a) One solution is the designing of a behaviour based on state. For the behaviour described above, the agent may have six states: (1) off-line: the state the agent is in during transit. If it receives a message from the server it reached, it enters the interrogative state; (2) interrogative: the state in which the agent sends a lot of messages to the local knowledge base agent, messages that match its desires. Then the agent enters into the listening state; (3) listening: The state in which the agent listens to messages received from the local knowledge base agent. As it receives new information, it updates its own knowledge base, namely its beliefs. Then, if there is no more server information that interests it, the agent sends a request for transport and enters the off-line state. If it has fulfilled all of its desires, it travels to the server of origin and enters the state of reporting. Otherwise, it returns to interrogative state; (4) transport ("dispatch"): The agent sends the server a request to be transported to a randomly chosen still unfrequented server or to the server of origin if it doesn't have any more unfulfilled desires; (5) Report: The agent communicates its convictions to the user and enters the state of suspension; (6) Suspension: The agent no longer acts on the environment; it can only be restarted from the outside for a new task or be closed if no longer useful.

b) Another solution is to use an event driven behaviour, which corresponds to the event-condition-action paradigm (or when-if-then). Note that this approach does not exclude the existence of states. It would be almost impossible for an agent to act with some degree of intelligence without maintaining some information on its state. The events for the same conduct are as follows:

Arrival (external event): The agent is informed by the server that it arrived. If there are still some unfulfilled desires, the agent prepares to ask questions, meaning it updates its belief that the current server can be useful (the agent does not ask any actual questions at this point, because asking questions would be acting on a decision, which is an internal event);

New message (external event): The agent receives a message from the local knowledge base agent in response to its questions. Therefore it updates its own knowledge base;

Selection of the action (internal event): If there are no external events to respond to, the agent can now be proactive and take the initiative. If there are no more unfulfilled desires and the agent is on the server of origin, it reports to the user and enter the suspend state. If there are no more unfulfilled desires but the agent is not on the server of origin, it travels to it. If there are still more unfulfilled desires but the local knowledge base agent does not have any more useful information, the agent travels to a randomly chosen still unfrequented server. If the local knowledge base agent has answers, the agent asks the questions relevant to its desires.

Note that the second method is more structured and closer to the cognitive processes of the human mind, although the agent functionality is exactly the same in both cases. The behaviour described above cannot be considered intelligent. An agent asks the local server agent a number of questions. After receiving responses, it updates its knowledge base. Desires that the local static agent did not responded to remain in the list of desires along with the new desires obtained from processing the responses. In the next round of questions, the agent will repeat some of the questions asked before and the local agent has no way to respond, because he has no knowledge. So a series of messages become unnecessary.

A first optimization is modelling the knowledge base on the servers by the agents. Agents store questions not answered and no longer address them to the same server. The storing of this information is not done in the list of convictions, but in a working memory, which also retains information on the agent's current state because it can be assumed that a knowledge base on a server can be updated between two visits of an agent. Therefore, with every new arrival on the server, this list of questions not answered will be reset.

7. Possibilities of cooperation between agents

To optimize the system, the possibility that agents can cooperate to solve problems was introduced. If a local agent on a server does not know the answer to a question, that answer may be known but by another visiting agent on the server, which has previously visited another server. Responses from the other agents can reduce the number of transports, thus demonstrating the advantages of cooperation.

The execution mechanism of an agent changes: The agent asks the local agent its questions until it stops receiving answers, then addresses (via the server, which performs the actual operation of broadcasting) questions to the other visiting agents. If it does not receive any response, it travels to another server. If it receives replies, it updates its internal knowledge base and then resumes its questions (obviously, only new questions) of the local knowledge base agent, the cycle resuming. For a refinement of cooperation, a so-called factor of cooperation was introduced, which indicates the probability that an agent will answer the questions of another agent. An uncooperative agent will have a null factor of cooperation, while a completely cooperative agent will have unitary factor of cooperation. However, inter-agent cooperation is done based on the submission of questions to all the agents on the server (broadcast). This increases the number of messages sent on the system. Note that the number of messages greatly increases when the average number of agents on a server is high (because each sends its questions to all the others).

8. Introduction of priority queues on servers

The strong increase in the number of messages while cooperating is mainly determined by the communication of questions to all other agents on the server. The reduction of the number of messages can be achieved by subtracting the number of active agents on the server, while maintaining the agent's possibility to cooperate. To this end, a priority mechanism for agents is introduced. Priorities are generated randomly when agents are initialized. In an actual case the priority system remains useful, as users themselves may have different priorities, by having different measures of the right to access system resources. The priorities of the users can thusly be transmitted to the agents that represent them. It was assumed that servers keep the agents in priority queues so that only a maximum number of agents can be run at a time. The introduction of agents in these execution queues is done in the descending order of priorities. Statements of equality are resolved randomly. There is an observed decrease in the number of messages sent (more than twice), while the number of transports is acceptable. From these measurements we can conclude that the introduction of priority queues on the servers greatly reduces the number of messages determined by the cooperation of agents, while the transport number remains at reasonable values.

Now the question arises: what is the best capacity for priority queues?

In a heterogeneous distributed real system, in which the computers may have different levels of performance, the capacity of the priority queue on a server can be in direct relation to the processing capacity of that computer.

Because some agents (those with lower priorities) are blocked on the server until the high priority agents are finished with their tasks, the average number of server cycles necessary to fulfil the desires increases when queue capacity decreases.

9. Acknowledgements

The software agent used for e-learning purposes proposed in this paper is based on the work of Dan Gâlea, Florin Leon and Mihai Horia Zaharia and was first discussed in "E-learning Distributed Framework using Intelligent Agents". The model described there was further developed and refined to include new concepts and features, such as a more efficient state and event driven behaviour, the capacity of the agents (in the said multi-agent system) to cooperate and exchange knowledge items and the introduction of priority queues to maintain server performance under the conditions created by the new communication capacities.

10. Conclusions

The proposed system shows a way to search for concepts in a distributed e-learning environment. The system development stages were presented. Initially, the agents addressed questions to the local knowledge base agents on the servers without modelling them. Then mobile search agents model the knowledge bases of the static server agents to avoid asking the same question twice if the local agent does not know the answer.

Further, the possibility for agents to cooperate was introduced, so that they could ask questions of each other if they were on the same server. Finally, priority queues were implemented on the servers, so that only a fixed maximum number of agents could be served at a time, in a descending order of priorities. As future research direction, we will try to archive a distributed implementation of the proposed model and develop the internal cognitive model of the agent, to include learning and reasoning mechanisms.

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